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# The Coronal Pulp Cavity Index: A Biomarker for Age Determination in Human Adults

ANDREA G. DRUSINI,* ORIELLA TOSO, AND CRISTINA RANZATO
*Dipartimento di Biologia, Università di Padova, Padova 35121, Italy*

*KEY WORDS* aging; teeth; X-ray; coronal pulp chamber

*ABSTRACT* The correlation between reduction of the coronal pulp cavity and chronological age was examined in a sample of 846 intact teeth from 433 individuals of known age and sex. Panoramic (rotational) radiography was used to measure the height (mm) of the crown (CH = coronal height) and the height (mm) of the coronal pulp cavity (CPCH = coronal pulp cavity height) of 425 premolars and 421 molars from 213 males and 220 females. The tooth-coronal index (TCI) after Ikeda et al. ([1985] Jpn. J. For. Med. *39:*244–250) was computed for each tooth and regressed on real age. The correlation coefficients ranged from −0.92 (molars, combined sample, right side) to −0.87 (female molars), with an S.E. of the estimate ranging from 5.88–6.66 years. Correlations were slightly higher in males than females. The equations obtained allowed estimation of age in a sample of 100 teeth from both sexes (not used for the regression) with an error of ±5 years in 81.4% of cases for male molars. The regression formulae for estimating age obtained from the recent sample were tested on a historical sample of 100 teeth from 100-year-old skeletons with an error of ±5 years in 70.37% of cases for male molars. This study illustrates the potential value of a little-known aging method which can be easily applied to estimate age in both living individuals and skeletal material of unknown age. Am J Phys Anthropol 103:353–363, 1997. 

Among the numerous methods of age estimation using teeth, the progressive diminution of the coronal pulp cavity has received far less research attention than, for example, dental wear (Brothwell, 1989; Benfer and Edwards, 1991; Lovejoy et al., 1985; Miles, 1958, 1963; Nowell, 1978; Smith, 1984; Solheim, 1988; Takei, 1984; Tomaru et al., 1993; Walker et al., 1991; Wei and Feng, 1984) or root dentin transparency (Bang, 1989; Bang and Ramm, 1970; Burns and Maples, 1976; Drusini, 1991; Drusini et al., 1990, 1991; Johanson, 1971; Lamendin and Cambray, 1981; Lamendin et al., 1990, 1992; Pilz, 1959; Solheim and Sundnes, 1980; Solheim, 1989, 1993). Other promising methods of age determination from teeth involve cementum annulation counting (Charles et al., 1986; Condon et al., 1986; Großkopf, 1990; Lipsinic et al., 1986; Lorton, 1988; Naylor et al., 1985; Solheim, 1990; Stott et al., 1982), counting of cross-striations and striae of Retzius in juveniles (Huda and Bowman, 1994, 1995), and aspartic acid racemization (Helfman and Bada, 1975, 1976; Masters, 1986; Ogino et al., 1985; Ogino and Ogino, 1988; Ohtani and Yamamoto, 1987, 1991, 1992; Ritz et al., 1990, 1993). Fluorescence from dentin and cementum (Kvaal and Solheim, 1989) needs further investigation.

After a review of the literature, Rösing (in press) deduced that the best method of age

*Correspondence to: Andrea G. Drusini, Dipartimento di Biologia, Università, via Trieste 75, I-35121 Padova, Italy. E-mail: drusini@civ.bio.unipd.it

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determination from teeth is the cementum annuli enumeration for both reliability and general applicability. Another option is racemization, which is roughly comparable in accuracy but not in applicability. It is best suited for forensic situations, as racemization is influenced by temperature conditions during the time following death. In fact, both cementum annulation and racemization methods are quite time-consuming and require sophisticated laboratory equipment. Mainly for these reasons, simpler methods need to be developed for practice in forensic osteology as well as historic and prehistoric skeletal biology.

In 1925, Bodecker identified that the apposition of secondary dentin was correlated to chronological age. Detailed studies of the pattern and rate of secondary dentin apposition in maxillary anterior teeth were performed by Philippas and Applebaum (1966, 1967, 1968) but without the goal of estimating age at death. Secondary dentin deposition was included in the method pioneered by Gustafson (1950) where dentin transparency and secondary dentin values showed the highest correlation with age. The studies of Nalbandian and Sognnaes (1960), Johanson (1971), Maples (1978), Metzger et al. (1980), Matsikidis and Schultz (1982), Solheim (1992), Kvaal and Solheim (1994), Kvaal (1995), and Kvaal et al. (1995) have all verified and demonstrated Gustafson's method. The Gustafson scoring system was based on the reduction of length of the pulp chamber with increasing age. A few authors (Lamendin et al., 1990; Morse, 1991), on the other hand, have argued that secondary dentin changes have not proven useful as a biomarker for age determination.

Secondary dentin is initiated after dentinogenesis (Costa, 1986). Dentin formation continues throughout life as layers of secondary dentin (also known as regular secondary dentin [Berkovitz et al., 1992]) are continuously deposited by odontoblasts lining the pulp chamber. Since regular secondary dentin is laid down on the pulpal surface of the primary dentin, the pulp cavity decreases in size with age (Gustafson, 1950; Balogh, 1957; Johanson, 1971; Hillson, 1986; Morse, 1991; Berkovitz et al., 1992; Solheim, 1992). The pattern for secondary dentin deposition varies with tooth type; for example, in molars the greatest dentin deposition is on the pulp chamber, and lesser amounts accumulate on the occlusal and lateral walls (Philippas and Applebaum, 1967, 1968; Morse, 1991).

## FORMATION OF SECONDARY DENTIN

There are two types of secondary dentin: one laid down continuously with increasing age (regular secondary dentin) and the other (irregular or tertiary dentin) occurring as a result of pathological conditions (Robinson and Boling, 1952; Johanson, 1971; Berkovitz et al., 1992). Regular secondary dentin contains fewer dentinal tubules dispersed regularly, and it may be difficult to distinguish from primary dentin. On the other hand, recognizing the two types of secondary dentin is relatively easy: in irregular secondary dentin the tubules are few in number, as in regular secondary dentin, but they are irregularly arranged (Hillson, 1986; Berkovitz et al., 1992). Worn and unworn teeth from the same dentition tend to show the same amount of regular secondary dentin (Burns and Maples, 1976).

As regular secondary dentin is deposited in larger amounts within the pulp chamber than on the roof, some authors have suggested that age has a greater influence than does dental wear or irritation on secondary dentin formation (Philippas and Applebaum, 1966; Berkovitz et al., 1992). Secondary dentin formation seems poorly influenced by attrition, but coronal secondary dentin formation may be increased by external factors. For example, changes in osmotic pressure throughout the pulp chamber have been claimed to influence secondary dentin formation (Solheim, 1992). Changes in the structure of dentin may also result from harmful or pathological stimuli, including caries, traumatic occlusion, and temperature extremes (Bang, 1989). Where dentin is subjected to acute damage (i.e., dental caries), some of the underlying odontoblasts die, while others lay down repair tissue. This irritation or response dentin is often known as irregular secondary dentin or tertiary dentin (Berkovitz et al., 1992). As the pulp cavity diminishes in size, the amount of secondary dentin can be used for age determination. Secondary dentin amount can be

detected using both histological and radiographic techniques. Whereas the radiographic technique is widely used to study dental development in children (Hess et al., 1932; Schour and Massler, 1941; Fanning, 1961; Moorrees et al., 1963; Demirjian et al., 1973; Anderson et al., 1976; Huda and Bowman, 1995), it is rarely used for age determination of adult individuals. Previous research (Ito, 1972, 1975; Ikeda et al., 1985) has demonstrated the change in the form of the anatomical crown and the constriction of the coronal pulp cavity using radiographs of histological sections of adult teeth. In a previous study, Drusini (1993), partially following the technique of Ikeda et al. (1985) (using intact teeth instead of histological sections and measurements taken directly off the radiographs), confirmed the negative correlation between the tooth-coronal index and age in 68 premolars and 98 molars of human adults. The correlation coefficients ranged from $-0.73$ (female molars) to $-0.89$ (female premolars), with standard errors ranging from 8.79–10.08 years.

Using an independent method, Kvaal et al. (1995) also found a strong coefficient of determination ($r^2$) ranging from 0.56–0.76 measuring the size of the pulp on dental intraoral radiographs. The sample consisted of incisors, canines, and premolars from 100 adult patients of the Dental Faculty Clinics in Oslo, Norway.

The first aim of this paper is to test the method of Ikeda et al. (1985) using a larger number of teeth from individuals of known sex and age and to test the regression equations on a randomly selected sample of teeth not used for the regression. In fact, neither Ito nor Ikeda tested the method for age estimation on a control sample. The second aim of the paper is to use the method for determining age at death of skeletons buried for approximately 100 years.

## MATERIALS AND METHODS

During the years 1994 and 1995, we had the opportunity to consult the radiographic records of the Cittadella Civic Hospital (Padua) and four private dental clinics from the Veneto region in northern Italy.

The sample studied consisted of panoramic X-ray photos of 846 intact teeth (425 premolars and 421 molars) from 433 individuals (213 males and 220 females) of known age from the Veneto region of northern Italy. The age of the individuals ranged from 9–76 years, with a mean of 34.68 years for the males and a mean age of 34.33 years for the females. We chose to use panoramic X-rays because most of the intraoral films were exposed to reveal pathologies such as caries, inflammatory processes, etc., and in most cases pulp cavity was filled by radiopaque material. With panoramic X-rays, on the other hand, it was possible to select teeth free from pathology with a distinct pulp chamber.

Panoramic radiography is a tomography of a curved layer where the X-ray tube and the film rotate around the face (Langland et al., 1982; Poyton, 1982). As the panoramic (rotational) radiographic technique is highly standardized, collecting teeth from several sources does not represent a problem for interpretation.

Although panoramic technique is seldom used in dental identification, it is suitable for the following reasons: 1) panoramic X-ray is a very common diagnostic tool, so a large number of cases can be obtained from clinicians and examined in a short time; 2) all the mandibular and the maxillary teeth are quickly recorded on a single film; and 3) gross lesions (fractures, unerupted teeth) are readily visible. Undoubtedly, panoramic X-ray shows a lack of detail in comparison with intraoral radiography, especially for anterior teeth, and the projection can be taken at only one angle. On the basis of these findings, we decided to include in this study only the teeth in which the pulp chamber was fully visible. Since we found that mandibular posterior teeth were normally better defined than all maxillary teeth, we considered mandibular premolars and molars (excluding the third) only. Previous studies have also demonstrated that differences between upper and lower dentition and teeth side are negligible in radiographic adult age determination (Ito, 1972, 1975; Ikeda et al., 1985).

The use of an index instead of absolute measures obviates the need to standardize tooth size on the photographs. So, whatever films are available, they can be used for age

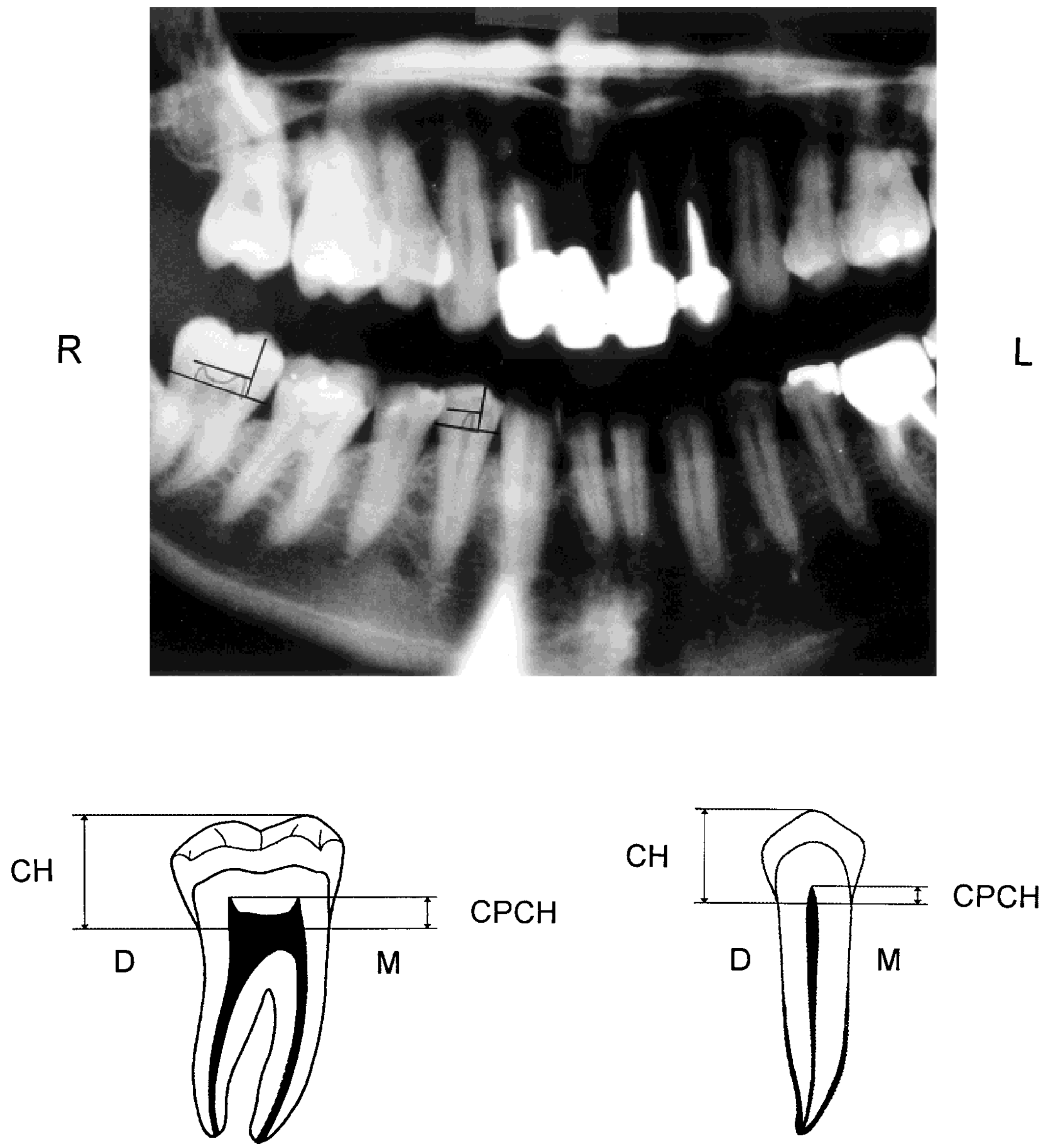


Fig. 1. Schematic representation of measurements taken off a panoramic radiograph with a digital caliper calibrated to the nearest 0.01 mm. The straight line traced between the distal (D) and mesial (M) enamel of the right first premolar and the right second molar represents the division between the anatomical crown and root. CH, coronal height; CPCH, coronal pulp cavity height. Tooth-coronal index (TCI) = CPCH × 100/CH (Planmeca OY 2002 CC panoramic X-ray: courtesy of Dr. Piero Angi).

determination (i.e., intra- and extraoral radiography).

### Approaches in this study

Using a digital caliper to the nearest 0.01 mm, two observers independently took the following measurements (in millimeters) on the photographs: height of the crown (CH) and height of the coronal pulp cavity (CPCH) (Fig. 1). A straight line traced between the cemento-enamel junction is the division between the anatomical crown and root. The

crown height was measured vertically from the cervical line to the tip of the highest cusp (following Moss et al., 1967). The coronal pulp cavity height was measured vertically from the cervical line to the tip of the highest pulp horn after Ikeda et al. (1985). Since dental wear influences the crown length, teeth with marked degrees of attrition (i.e., from stage 5 to stage 8 after Smith [1984]) were excluded from this study.

With the mean of the measurements of two observers, the tooth-coronal index (TCI) for each tooth was then calculated as follows:

$$\mathrm{TCI} = \mathrm{CPCH} \times 100/\mathrm{CH}.$$

The teeth were divided into premolars and molars for statistical analysis. Simple linear regression using the STATISTICA™ package of Statsoft, Inc. (Tulsa, OK) was carried out by regressing the tooth-coronal index (TCI) against actual age for each group of teeth for males and females and for the combined sample. The usual measure of the success of a regression is $r^2$ ("goodness of fit") (Walker et al., 1991). However, our purpose was to predict age from observations of the tooth-coronal index, in which case predictive accuracy is a better evaluation of our model's performance. Since sample sizes were quite large, the total sample was divided into two subsets to measure predictive accuracy of the method. The regression line can then be fitted using one subset so that its predictive accuracy can be tested using the other subset. We used 375 premolars (178 male and 197 female) and 371 molars (182 male and 189 female) as the main subset. We also calculated the TCI in young individuals (under 20) in order to fix the upper limit of the CPCH and in old individuals (over 70) to fix the lower limit of the CPCH. Since it is difficult to find intact teeth at the 71–80 year age range (see Gustafson, 1950; Ikeda et al., 1985), we decided to include also the 71–80 age range individuals in the database for future studies. To measure the predictive accuracy, we employed two randomly selected teeth subsets: 100 teeth (50 premolars and 50 molars) from the clinical sample and 100 teeth (50 premolars and 50 molars) from a historical sample of known age and sex belonging to the skeletal collection of the Department of Biology, University of Padua. The historical skeletons (N = 50; 25 males and 25 females) all are from Italians who died between 1890 and 1930. Age, sex, occupation, and cause of death are recorded in the archive of the Department of Biology (Drusini et al., 1991; Drusini, 1994). The radiographs of the teeth from the historical sample were taken using extraoral projections following the method described by Poyton (1982). The projections can be undertaken with a dental apparatus, but we obtained better results with a general purpose high output apparatus using a rotating anode. We used a movable grid to improve the radiograph. The focus-film distance was 90 cm (36 inches).

## RESULTS

Table 1 shows the extent of the TCI by age category. Replicate measurements were nearly identical, with an interobserver error of 3.8%. Means, medians, ranges, and standard deviations for males, females, and the combined sample are also compared. As suggested by Lovejoy et al. (1985), the inaccuracy (mean absolute error) and bias (mean error) for each decade in the three samples for the two types of teeth are also provided (Table 2).

The simple linear regression results are shown in Table 3. The correlations were especially significant for male molars ($r = -0.92$; $r^2 = 0.85$). The deviations (i.e., true age minus predicted value of the regression line) were slightly smaller for males. Figures 2 and 3 illustrate the scatterplots and the regression lines of age (Y) and the TCI (X) values for premolars and molars (combined sample). The regression equations for premolars are as follows:

$$Y = 77.617 - 1.4636X \text{ combined sample}$$
$$Y = 79.679 - 1.5356X \text{ male}$$
$$Y = 75.523 - 1.3896X \text{ female,}$$

while for molars they are

$$Y = 76.073 - 1.4576X \text{ combined sample}$$
$$Y = 77.747 - 1.5066X \text{ male}$$
$$Y = 73.846 - 1.3906X \text{ female.}$$

The regression equations were tested on a randomly selected sample totalling 200 teeth

*TABLE 1. Percentage extent of the tooth-coronal index (TCI) by age and sex*[1]

| Age | N | Mean | Median | S.D. | Min | Max |
|---|---|---|---|---|---|---|
| Males, premolars | | | | | | |
| 11–20 | 28 | 38.71 | 39.11 | 4.50 | 25.00 | 45.82 |
| 21–30 | 62 | 34.80 | 34.97 | 3.68 | 24.35 | 44.00 |
| 31–40 | 28 | 29.59 | 30.44 | 3.91 | 20.24 | 34.24 |
| 41–50 | 27 | 22.38 | 22.39 | 3.61 | 14.17 | 30.10 |
| 51–60 | 19 | 18.07 | 17.90 | 4.22 | 11.84 | 26.40 |
| 61–70 | 14 | 13.10 | 13.37 | 2.94 | 6.71 | 18.85 |
| Males, molars | | | | | | |
| 11–20 | 33 | 39.63 | 40.32 | 4.17 | 22.46 | 45.05 |
| 21–30 | 62 | 34.21 | 34.06 | 4.08 | 22.92 | 41.96 |
| 31–40 | 31 | 28.33 | 28.94 | 4.27 | 17.87 | 36.50 |
| 41–50 | 23 | 20.98 | 19.87 | 4.14 | 16.30 | 36.46 |
| 51–60 | 18 | 18.21 | 17.76 | 4.63 | 11.11 | 29.29 |
| 61–70 | 15 | 11.54 | 11.99 | 4.39 | 0.00 | 18.84 |
| Females, premolars | | | | | | |
| 11–20 | 27 | 38.97 | 39.01 | 3.80 | 30.48 | 44.17 |
| 21–30 | 54 | 34.36 | 35.27 | 4.29 | 22.00 | 41.88 |
| 31–40 | 47 | 29.94 | 30.83 | 4.83 | 15.52 | 40.42 |
| 41–50 | 45 | 22.50 | 22.72 | 4.30 | 12.28 | 37.60 |
| 51–60 | 16 | 19.15 | 17.96 | 4.05 | 13.70 | 25.87 |
| 61–70 | 8 | 13.12 | 12.29 | 3.16 | 8.93 | 18.30 |
| Females, molars | | | | | | |
| 11–20 | 31 | 39.05 | 39.54 | 3.24 | 30.70 | 44.88 |
| 21–30 | 58 | 33.30 | 33.62 | 4.07 | 20.18 | 43.70 |
| 31–40 | 46 | 28.71 | 29.10 | 4.86 | 20.16 | 38.13 |
| 41–50 | 37 | 21.49 | 21.87 | 4.02 | 12.55 | 30.95 |
| 51–60 | 11 | 17.07 | 17.98 | 3.36 | 12.56 | 21.58 |
| 61–70 | 6 | 13.98 | 14.52 | 4.86 | 8.20 | 20.11 |
| Combined sample, premolars | | | | | | |
| 11–20 | 55 | 38.83 | 39.02 | 4.30 | 25.00 | 45.82 |
| 21–30 | 116 | 34.60 | 35.15 | 3.97 | 22.00 | 44.00 |
| 31–40 | 75 | 29.81 | 30.83 | 4.49 | 15.52 | 40.42 |
| 41–50 | 72 | 22.45 | 22.62 | 4.02 | 12.28 | 37.60 |
| 51–60 | 35 | 18.56 | 17.90 | 4.12 | 11.84 | 26.40 |
| 61–70 | 22 | 13.11 | 13.29 | 2.95 | 6.71 | 18.85 |
| Combined sample, molars | | | | | | |
| 11–20 | 64 | 39.35 | 39.97 | 3.73 | 22.46 | 45.05 |
| 21–30 | 120 | 33.77 | 33.67 | 4.08 | 20.18 | 43.70 |
| 31–40 | 77 | 28.56 | 28.94 | 4.61 | 17.87 | 38.13 |
| 41–50 | 60 | 21.29 | 21.17 | 4.04 | 12.55 | 36.46 |
| 51–60 | 29 | 17.78 | 17.89 | 4.16 | 11.11 | 29.29 |
| 61–70 | 21 | 12.24 | 12.04 | 4.55 | 0.00 | 20.11 |

[1] Measurements are in millimeters.

(100 premolars and 100 molars of both sexes). The sample comprised two subgroups: a recent sample (RS) made up of 100 teeth (50 premolars and 50 molars) from the clinical sample that were not used for the regression analysis and a historical sample (HS) of 100 isolated teeth (50 premolars and 50 molars) taken from the skeletal collection of the Department of Biology. Three equations were used: one for males, one for females, and one for the sexes combined. Results are shown in Tables 4 and 5. The best estimation was obtained for male molars of the recent sample with an error of $\pm 5$ years in 81.4% of the cases. No significant difference exists between antimeres or between premolars as between molars.

## DISCUSSION

Dental radiographs of adult teeth are rarely used in age estimation. However, a simple, nondestructive method can be employed for aging skeletal remains and utilized in living individuals.

The length of the coronal pulp cavity shows a significant correlation with chronological age; the coefficients of correlation we found for molars are practically the same as those of Ikeda et al. (1985). Sex appears to have no significant influence on age determination using the tooth-coronal index, so sex-specific formulae are not warranted for age determination in specimens of unknown sex. The index obviates the need to standard-

*TABLE 2. Results of inaccuracy and bias tests*

| | Male | | | Female | | | Combined sample | | |
|---|---|---|---|---|---|---|---|---|---|
| Age | N | Inaccuracy | Bias | N | Inaccuracy | Bias | N | Inaccuracy | Bias |
| Premolars | | | | | | | | | |
| 11–20 | 28 | 5.92 | −3.76 | 27 | 5.31 | −4.18 | 55 | 5.65 | −3.96 |
| 21–30 | 62 | 4.03 | −0.94 | 54 | 4.86 | −2.33 | 116 | 4.40 | −1.63 |
| 31–40 | 28 | 3.77 | 0.14 | 47 | 5.01 | 0.59 | 75 | 4.65 | 0.47 |
| 41–50 | 27 | 5.14 | 0.49 | 45 | 3.82 | 1.26 | 72 | 4.34 | 0.87 |
| 51–60 | 19 | 5.23 | 4.00 | 16 | 5.37 | 5.20 | 35 | 5.21 | 4.65 |
| 61–70 | 14 | 5.04 | 4.00 | 8 | 7.83 | 7.83 | 22 | 6.03 | 5.69 |
| Molars | | | | | | | | | |
| 11–20 | 33 | 4.76 | −2.49 | 31 | 4.59 | −2.96 | 64 | 4.64 | −2.65 |
| 21–30 | 62 | 4.30 | −1.07 | 58 | 4.76 | −2.00 | 120 | 4.53 | −1.51 |
| 31–40 | 31 | 3.40 | −0.76 | 46 | 4.75 | 0.43 | 77 | 4.25 | −0.10 |
| 41–50 | 23 | 4.33 | −0.45 | 37 | 4.88 | 1.50 | 60 | 4.55 | 0.52 |
| 51–60 | 18 | 6.25 | 5.24 | 11 | 5.06 | 5.06 | 29 | 5.69 | 5.25 |
| 61–70 | 15 | 5.26 | 3.84 | 6 | 10.58 | 10.58 | 21 | 6.78 | 6.19 |

*TABLE 3. Equations predicting age (Y) from proportion of tooth-coronal index (X) by type of tooth, side, and tooth position for males, females, and sexes combined*[1]

| | N | Y | Intercept | Slope | r | $r^2$ | S.E.E. |
|---|---|---|---|---|---|---|---|
| Premolars | | | | | | | |
| M + F | 375 | 35.16 | 77.617 | −1.4636 | −0.89 | 0.80 | 6.40 |
| M + F, right side | 158 | 35.29 | 78.422 | −1.4666 | −0.90 | 0.82 | 6.07 |
| M + F, left side | 217 | 35.00 | 76.764 | −1.4526 | −0.89 | 0.78 | 6.66 |
| M + F (P1) | 159 | 35.38 | 75.466 | −1.4036 | −0.88 | 0.77 | 6.62 |
| M + F (P2) | 216 | 35.00 | 79.241 | −1.5066 | −0.91 | 0.82 | 6.22 |
| Male | 178 | 35.02 | 79.679 | −1.5356 | −0.91 | 0.83 | 6.30 |
| Female | 197 | 35.30 | 75.523 | −1.3896 | −0.88 | 0.77 | 6.47 |
| Molars | | | | | | | |
| M + F | 371 | 33.84 | 76.073 | −1.4576 | −0.90 | 0.81 | 6.29 |
| M + F, right side | 166 | 34.23 | 76.715 | −1.4646 | −0.92 | 0.84 | 5.88 |
| M + F, left side | 205 | 33.59 | 74.953 | −1.4336 | −0.88 | 0.78 | 6.53 |
| M + F (M1) | 192 | 30.59 | 74.808 | −1.4456 | −0.91 | 0.82 | 6.22 |
| M + F (M2) | 179 | 37.33 | 76.210 | −1.4276 | −0.89 | 0.79 | 6.24 |
| Male | 182 | 34.35 | 77.747 | −1.5066 | −0.92 | 0.85 | 6.23 |
| Female | 189 | 33.36 | 73.846 | −1.3906 | −0.87 | 0.77 | 6.32 |

[1] F = female; M = male; S.E.E. = standard error of the estimate.

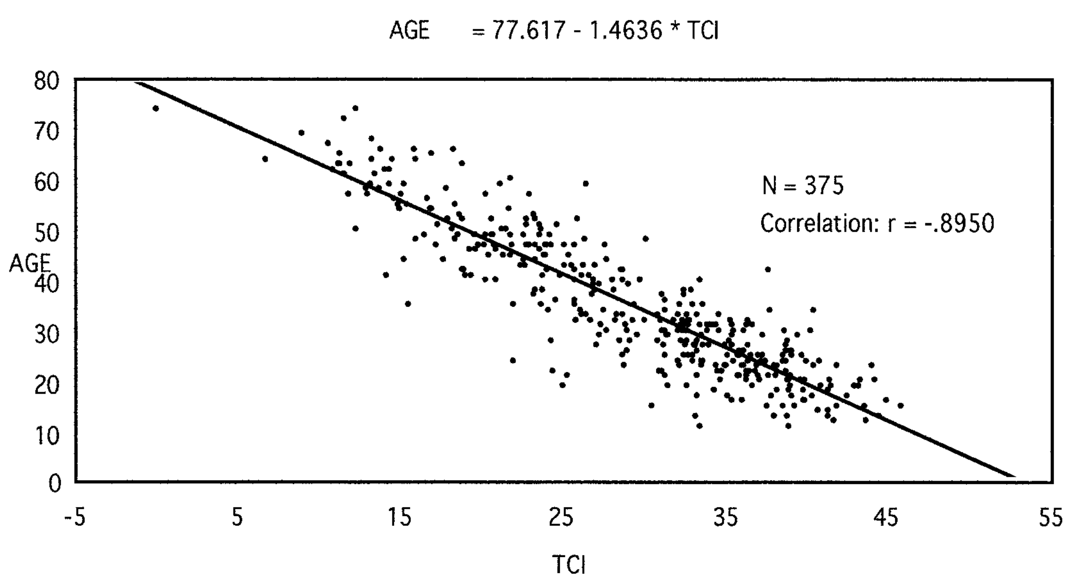


Fig. 2. Scatterplot and regression line of age on TCI values for premolars (combined sample).

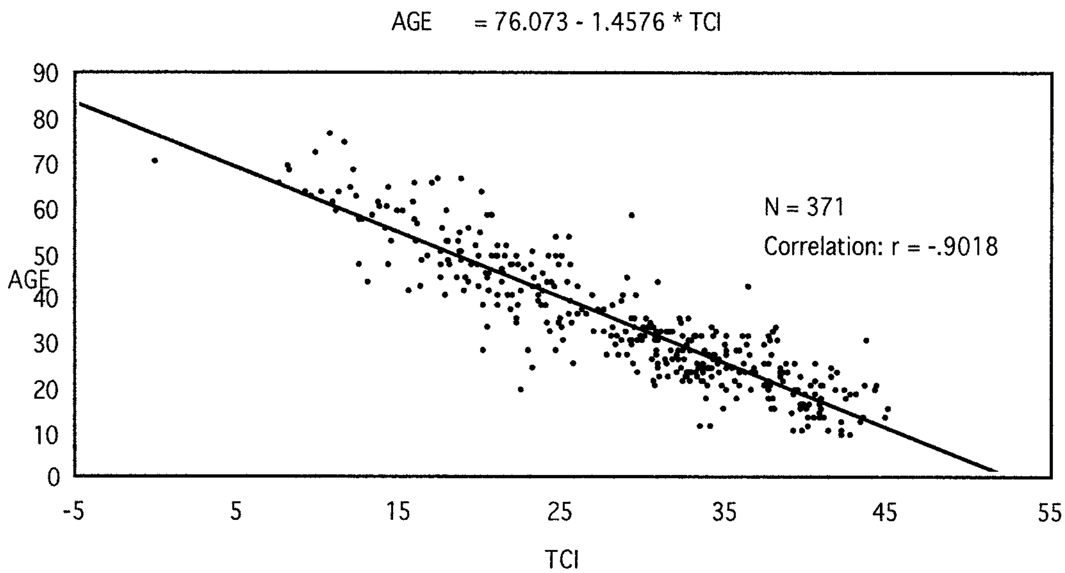


Fig. 3. Scatterplot and regression line of age on TCI values for molars (combined sample).

*TABLE 4. Age estimation (years) on a test sample of 50 premolars and 50 molars of known age and sex from the recent sample (RS)*

| | Male + female | Male | Female |
|---|---|---|---|
| Premolars | | | |
| N | 50 | 31 | 19 |
| Mean actual age (years) | 35.92 | 34.29 | 38.57 |
| Mean estimated age (years) | 32.41 | 31.92 | 33.21 |
| Minimum error of the estimate | 0.16 | −0.03 | 0.58 |
| Maximum error of the estimate | 18.65 | 17.46 | 18.65 |
| Inaccuracy | 3.50 | 2.36 | 5.36 |
| Bias | 3.43 | 3.25 | 4.06 |
| Percentage error of ±5 years | 60.0 | 64.5 | 57.9 |
| Molars | | | |
| N | 50 | 27 | 23 |
| Mean actual age (years) | 39.7 | 40.11 | 39.21 |
| Mean estimated age (years) | 36.68 | 37.46 | 35.83 |
| Minimum error of the estimate | −0.08 | 0.43 | −0.32 |
| Maximum error of the estimate | 18.28 | 17.12 | 14.09 |
| Inaccuracy | 2.99 | 2.67 | 3.30 |
| Bias | 2.99 | 2.67 | 3.30 |
| Percentage error of ±5 years | 78.0 | 81.4 | 60.8 |

*TABLE 5. Age estimation (years) on a test sample of 50 premolars and 50 molars of known age and sex from the historical sample (HS)*

| | Male + female | Male | Female |
|---|---|---|---|
| Premolars | | | |
| N | 50 | 25 | 25 |
| Mean actual age (years) | 31.30 | 32.92 | 29.68 |
| Mean estimated age (years) | 31.77 | 33.74 | 29.79 |
| Minimum error of the estimate | ±0.20 | 0.20 | −0.20 |
| Maximum error of the estimate | 14.82 | 14.82 | 14.34 |
| Inaccuracy | 5.59 | 5.52 | 5.67 |
| Bias | 0.47 | 0.80 | 0.11 |
| Percentage error of ±5 years | 58.00 | 60.00 | 56.00 |
| Molars | | | |
| N | 50 | 25 | 25 |
| Mean actual age (years) | 35.92 | 34.80 | 37.04 |
| Mean estimated age (years) | 37.55 | 35.26 | 39.84 |
| Minimum error of the estimate | 0.35 | −0.89 | 0.35 |
| Maximum error of the estimate | 15.24 | 8.62 | 15.24 |
| Inaccuracy | 5.18 | 4.26 | 6.10 |
| Bias | 1.63 | 0.46 | 2.80 |
| Percentage error of ±5 years | 62.00 | 76.00 | 48.00 |

ize tooth size on the photographs, so dental X-rays obtained with different techniques can be used. The strength of the correlation is higher if compared to root dentin transparency on a sample of teeth from the same population (Drusini, 1991; Drusini et al., 1991). The panoramic technique has the advantage of displaying all the mandibular

and maxillary teeth on a single film, although it is suitable mainly for posterior mandibular teeth. Intraoral and extraoral films are preferred for anterior teeth and for identification of isolated teeth.

The tooth coronal index is a reliable biomarker for age assessment in living individuals of unknown personal data for human biology and dental anthropology and in forensic osteology. This method is not time-consuming, nor does it require highly specialized equipment. The high correlations show that the extent of the coronal pulp cavity is easily visible in premolars and molars using panoramic (or bitewings/periapical) radiography.

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